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14. ABSTRACT

Under support from the US Air Force Office of Scientific Research (AFOSR), an Antenna and Radar Cross Section (RCS) Instrumentation System operating over the 45 MHz - 26.5 GHz frequency range was developed and integrated, leading to the completion of the Anechoic Chamber Facility at the University of Nebraska-Lincoln (UNL). Some key features of the antenna and RCS measurement system include: (a) Frequency band: 45 MHz - 26.5 GHz; (b) RCS vs. frequency and azimuth measurement capability; (c) Full polarimetric scattering matrix capability; (d) One- and two-dimensional high resolution imaging capability; (e) Antenna measurement capability; and (f) Fully automated measurement and processing.

In this final report, we provide a brief overview of the system configuration and technical specifications, and present typical measurement examples.

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Final Report

INSTRUMENTATION FOR ANTENNA AND RADAR CROSS SECTION MEASUREMENTS

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Contents

ABSTRACT

Under support from the US Air Force Office of Scientific Research (AFOSR), an Antenna and Radar Cross Section (RCS) Instrumentation System operating over the 45 MHz - 26.5 GHz frequency range was developed and integrated, leading to the completion of the Anechoic Chamber Facility at the University of Nebraska-Lincoln (UNL). Some key features of the antenna and RCS measurement system include:

- Frequency band: 45 MHz - 26.5 GHz;
- RCS vs. frequency and azimuth measurement capability;
- Full polarimetric scattering matrix capability;
- One- and two-dimensional high resolution imaging capability;
- Antenna measurement capability; and
- Fully automated measurement and processing.

In this final report, we provide a brief overview of the system configuration and technical specifications, and present typical measurement examples.

1 INTRODUCTION

The University of Nebraska-Lincoln (UNL) has a long history of research activities in the UHF, microwave and millimeter-wave frequency ranges. Research has been carried out in the area of radar remote sensing of both natural environment, such as soil and vegetation, and man-made targets, such as ground vehicle, aerial targets, and so on. The development of an Anechoic Chamber Facility has been a priority at the University of Nebraska for several years. In early 1997, the University took the first major step towards this goal by supporting the construction of the anechoic chamber at a cost of $100,000 from internal funds. The next step in the development of the facility is the development and integration of the measurement instrumentation, which we are addressing in this report.

Under support from the US Air Force Office of Scientific Research (AFOSR), an antenna and Radar Cross Section (RCS) Instrumentation System operating over the 45 MHz - 26.5 GHz frequency ranges was developed, leading to the completion of the Anechoic Chamber Facility at UNL. This project is part of a broader strategic plan that has been developed at the University of Nebraska to improve the research competitiveness of the university for the next several years.

In this report, we provide a brief overview of the system configuration and technical specifications, and present sampled measurement results. The remainder of this report is organized as follows. In section 2, the configuration of the antenna and RCS instrumentation system is described. The technical specifications and key features of each subsystem are summarized. Section 3 presents some typical RCS measurement examples. We conclude the work in Section 4.

2 SYSTEM CONFIGURATION AND TECHNICAL SPECIFICATIONS

The overall indoor range antenna and RCS measurement system is illustrated in Figure 1. The system consists of five major subsystems, namely,

- Microwave anechoic chamber;
- Transmitter and receiver subsystem;
- Antenna subsystem;

- Positioner subsystem; and
- Control and processing computer and software.

We describe the configuration and major technical specifications of each of the subsystems in this section.

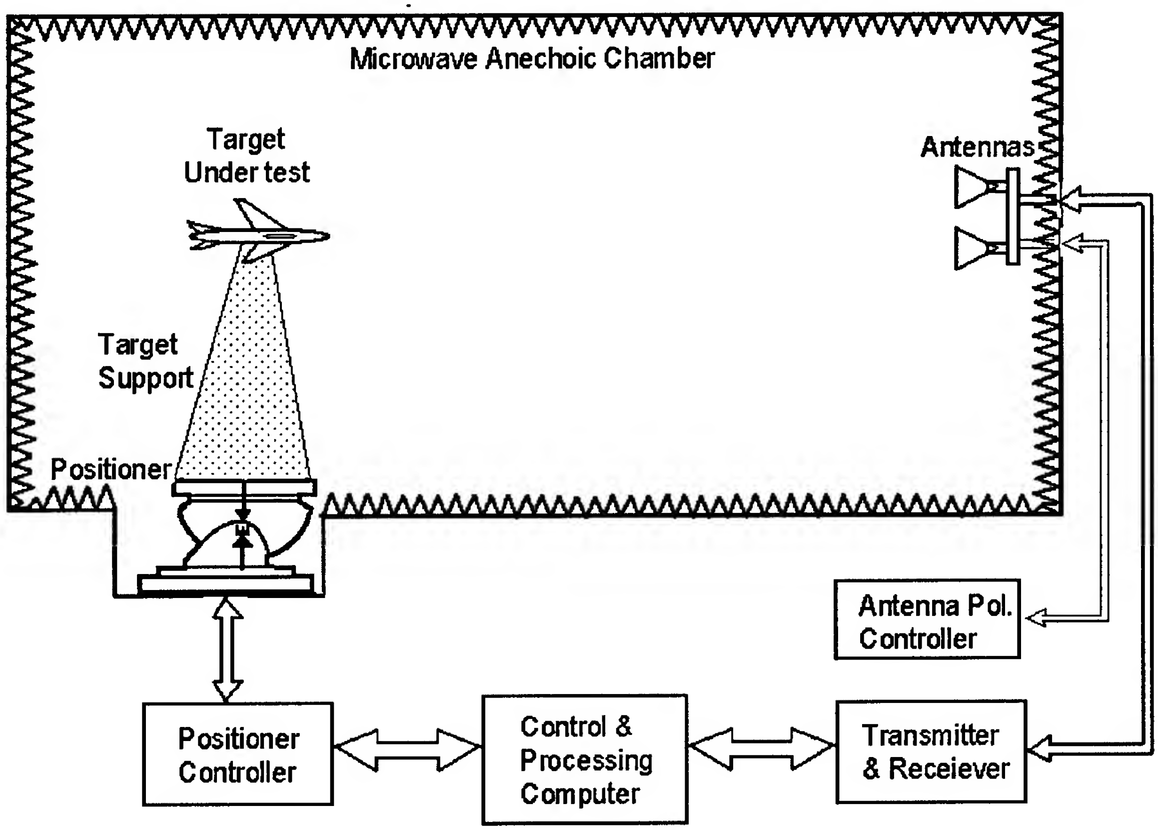

Figure 1: Indoor range for RCS and Antenna Measurement.

2.1 The Microwave Anechoic Chamber

The microwave anechoic chamber was constructed in 1997. The chamber is located in Room 319, Walter Scott Engineering Center, and is approximately 20' x 28' in area, with a height of 15'. The chamber is fully shielded electromagnetically, thereby permitting its usage for EMC/EMI testing purposes.

2.2 Transmitter and Receiver Subsystem

The transmitter and receiver subsystem is mainly composed of an Agilent 8530A microwave receiver, an Agilent 83631B frequency synthesizer, and an Agilent 8511A frequency converter, as shown in Figure 2.

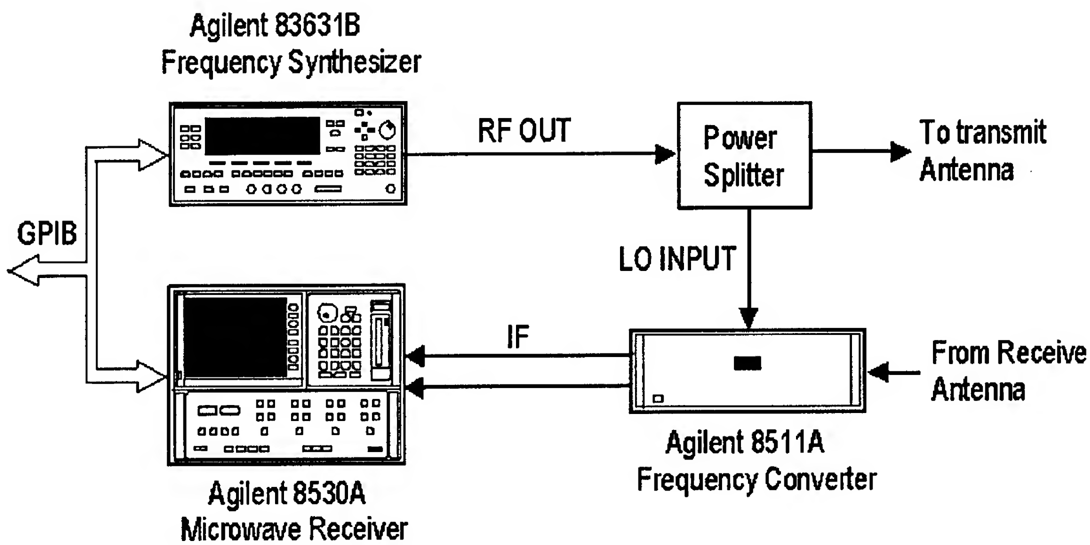

Figure 2: Transmitter and receiver subsystem.

This configuration is similar to the Agilent 85301C antenna and RCS measurement system which provides the instrumentation necessary to perform automated antenna pattern or RCS measurements. It operates from 45 MHz to 26.5 GHz with the Agilent 8511A harmonic sampler-based frequency converter. A capability extending the frequency range from 45 MHz to 50 GHz by substituting an Agilent 8511B is also possible. This system provides an economical solution while maintaining superb performance for indoor ranges. The key features and specifications are:

- Operating frequency: 45 MHz to 26.5 GHz;
- Measurement speeds of up to 5000 data points per second;
- Fast multiple-channel measurements;
- Excellent microwave performance and accuracy;
- Manual or automated operation;

- Built-in graphical display and analysis capability.

2.3 Antenna Subsystem

The antenna subsystem consists of two DRH-0118 ultra wideband antennas and the antenna polarization controller. The DRH-0118 ultra wideband, double-ridged horn antenna is linearly polarized and operates over a frequency range of 1 to 18 GHz. These antennas have gain, bandwidth and power handling characteristics which are ideal for indoor range antenna and RCS testing. In addition, these horns have low dispersion when used with short-pulse signals. This characteristic combined with a wide instantaneous bandwidth and relatively large power gain makes these antennas ideal for ultra wideband RCS and imaging applications.

The polarization of the two antennas can be separately and remotely controlled by the antenna polarization controller. This feature combined with the low cross polarization characteristics of the antennas makes it easier to measure the full polarization scattering matrix of the target under test.

The key features and specifications of the antenna subsystem are:

- Bandwidth: 1-18 GHz;
- Gain, typical at 10 GHz: 12 dBi;
- Polarization: Linear combination with remote control;
- Maximum input power: 300 W;
- Cross polarization: $\leq$ -20 dB;
- Front-to-back ratio: $\geq$ 20 dB.

2.4 Positioner Subsystem

The positioner subsystem is composed of an ORBIT AL-160-1 azimuth positioner and an ORBIT AL-4146-2 power control unit. The AL-160-1 azimuth positioner has a totally enclosed designs of the drive gear train and data take-off. The angular position readout accuracy up to 0.005. The AL-4146-2 provides precision motor drive for antenna/target positioners, and speed regulation and control with a high degree of accuracy. This unit is a four quadrant servo power amplifier for DC motors, especially designed and built to

be used as a motor driver for antenna/target positioners which incorporate wound field or permanent magnet servo motors of various ratings. The AL-4146-2 can be controlled in any of 4 modes: (a). Manually through its own control panel; (b). Manually, through a hand-held AL-4146-2L Local Control Unit (LCU), via a cable. When the LCU is connected, the PCU front panel is disabled; (c). Manually, through the ORBIT/FR controller's control panel; and (d). By a computer, via. an ORBIT/FR's controller.

The key features and specifications of the positiner subsystem are:

- Vertical Load: 150 lbs;
- Nominal Speed (minimum): 1.5 rpm;
- Rotary Encoder/Synchro Accuracy: 0.02^o;
- Maximum Backlash: 0.08^o;
- Control modes: Remote/local, automatic/manual.

2.5 Control and Processing Computer and Software

A DELL Dimension XPS T700r computer is used as the control and processing computer. The control and measurement software consists of the ORBIT/FR 959 automated RCS/ antenna measurement workstation, version 8.1, and the ORBIT/FR DataPro RCS/antenna data presentation and analysis, version 8.1. A two-dimensional inverse synthetic aperture radar (ISAR) imaging software is under development and near its finalization.

The system software performance characteristics include:

- Capabilities: frequency and position selection, positioner movement control;
- Data acquisition: Real time display, target peaking, and batch data collection, processing, analysis and hardcopy test results;
- Data calibration: reference standards support, pre-gating,and space-loss correction;
- Data analysis: 1-D time domain processing, software gating, superresolution processing, and 2-D ISAR imaging;
- Data presentation and exporting.

3 SAMPLED TEST RESULTS

Extensive experiments have been conducted using the RCS/antenna instrumentation system. We present a few examples in this section.

Figure 3 and Figure 4 demonstrate the RCS measurements as a function of target azimuthal angle at a fixed frequency. The measurement parameters are as follows: frequency 10 GHz, azimuth angle -180^o to $+180^o$, VV polarization. The target is a trihedral corner reflector of side length about 14 cm. The theoretical RCS is 2.5 dBsm. A metal sphere of diameter 25.4 cm was used as the RCS calibrator. Figure 3 shows the RCS magnitude vs. azimuthal angle, while Figure 4 illustrates the RCS phase vs. azimuthal angle. It is seen that the special RCS pattern of the trihedral corner reflector is well characterized by the measured data, and the measured RCS value is very close to the theoretical value.

Figure 5 and Figure 6 show the RCS measurement of a metal sphere of diameter 25.4 cm as a function of frequency. The measurement parameters are: frequency 5 GHz to 12 GHz, stepped in an increment of 35 MHz, VV polarization. Another metal sphere of diameter 63.8 cm was used as the calibrator. A 6.4 ns range gate was applied in the post-processing. Figure 5 and 6 illustrate the RCS magnitude and phase vs. frequencies, respectively. The theoretical RCS value of the target sphere is -13 dBsm. It is seen that the measured data is coincident to the theoretical value. Figure 6 also demonstrates the good phase capability of the instrumentation system.

Finaly, two-dimensional (2-D) high resolution ISAR imaging experiments were conducted. Figure 7 demonstrates the 2-D high resolution imaging capability of the instrumentation system. The target under imaging is an airplane model. The imaging parameters are: frequency 8-15 GHz, stepped in an increment of 35 MHz, azimuthal angle $-10^o - +10^o$ in the nose-on direction, with an increment of 0.5^o, HH polarization. A back-projection algorithm is used in the ISAR image processing. Figure 7 illustrates both the 3-D isometric graph and the 2-D contour image of the airplane model. It is observed that very high 2-D resolution was obtained, and the dynamic range of the image is better than 40 dB.

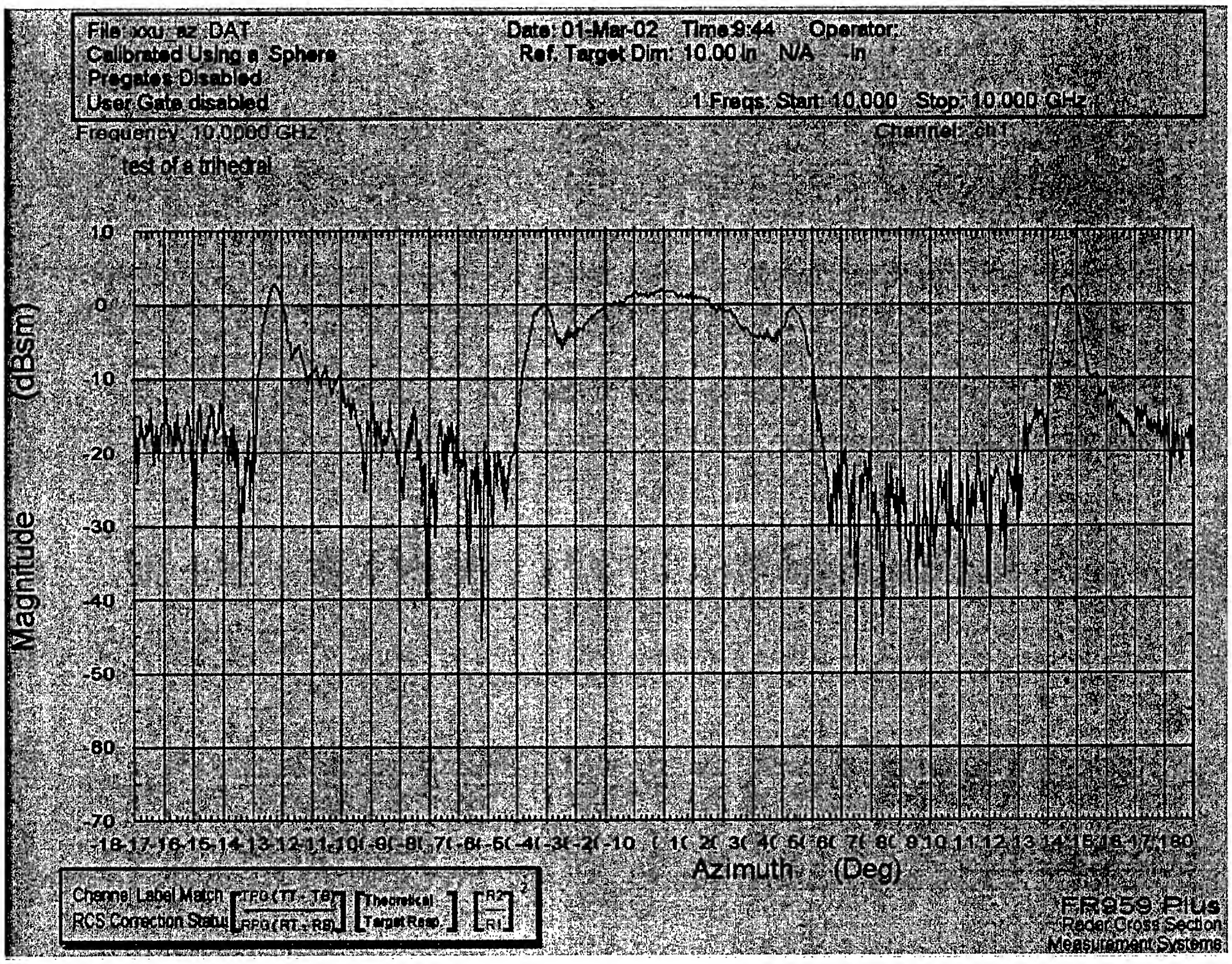

Figure 3: RCS magnitude vs. azimuth angle of a trihedral corner reflector.

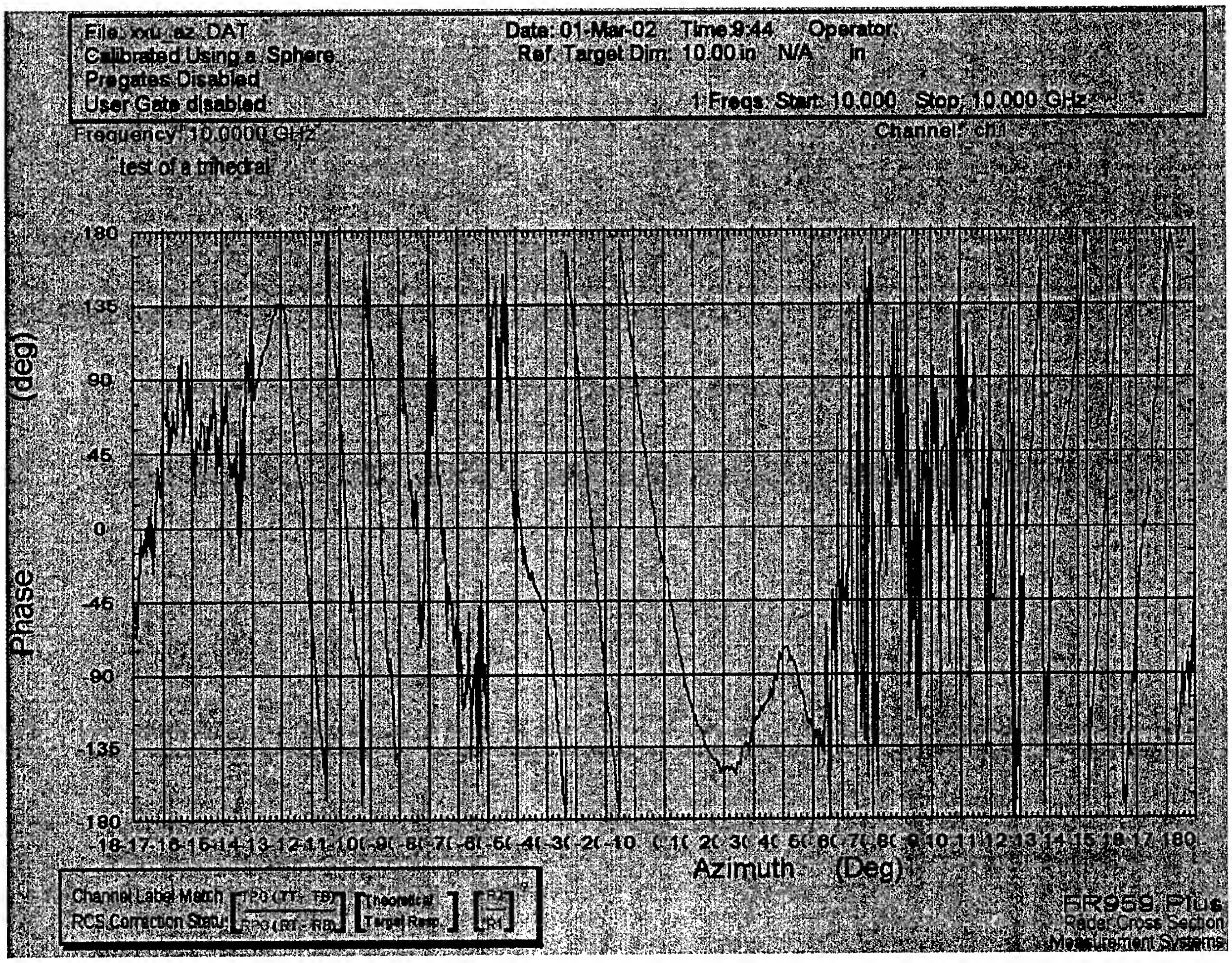

Figure 4: RCS phase vs. azimuth angle of a trihedral corner reflector.

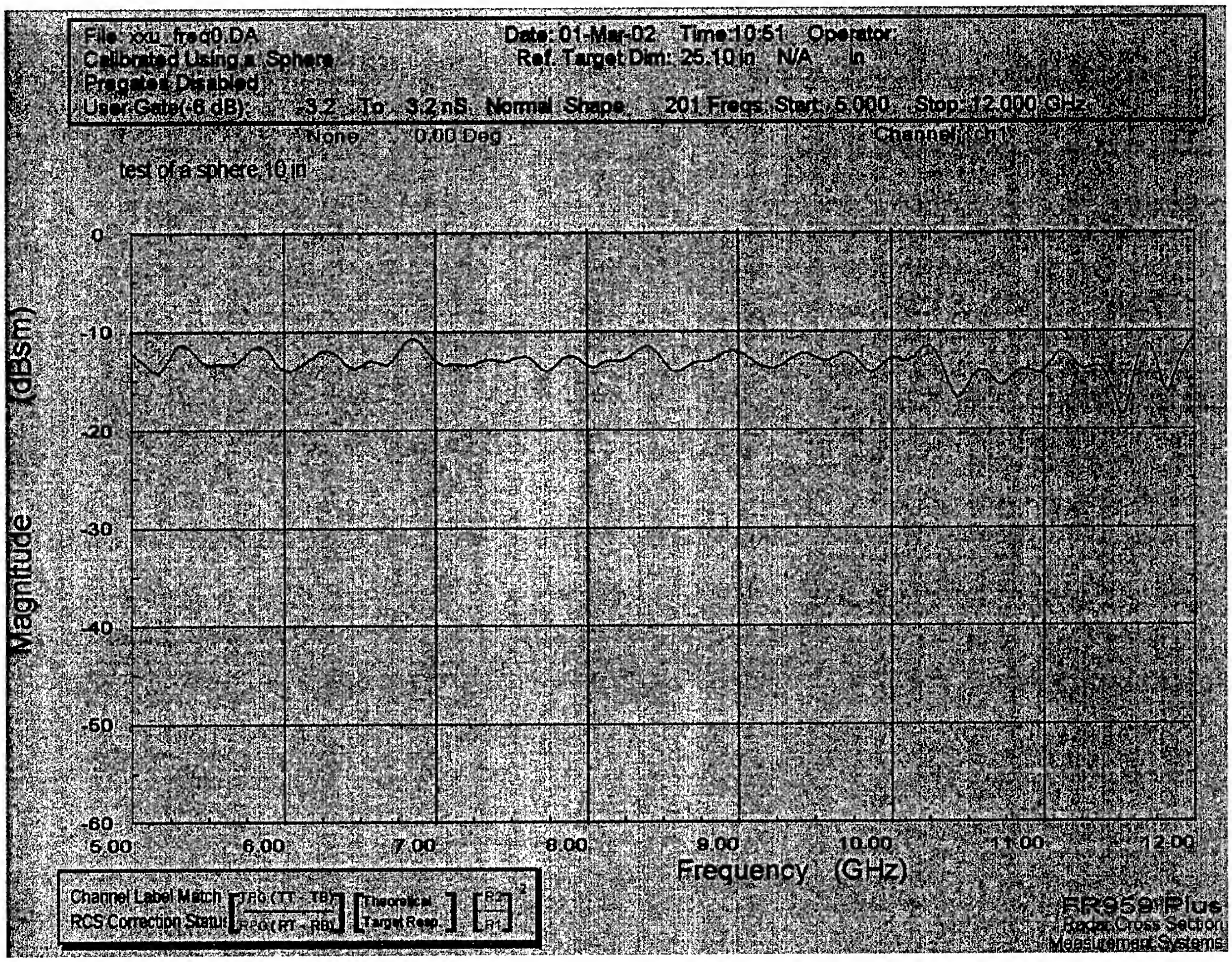

Figure 5: RCS magnitude vs. frequency of a metal sphere.

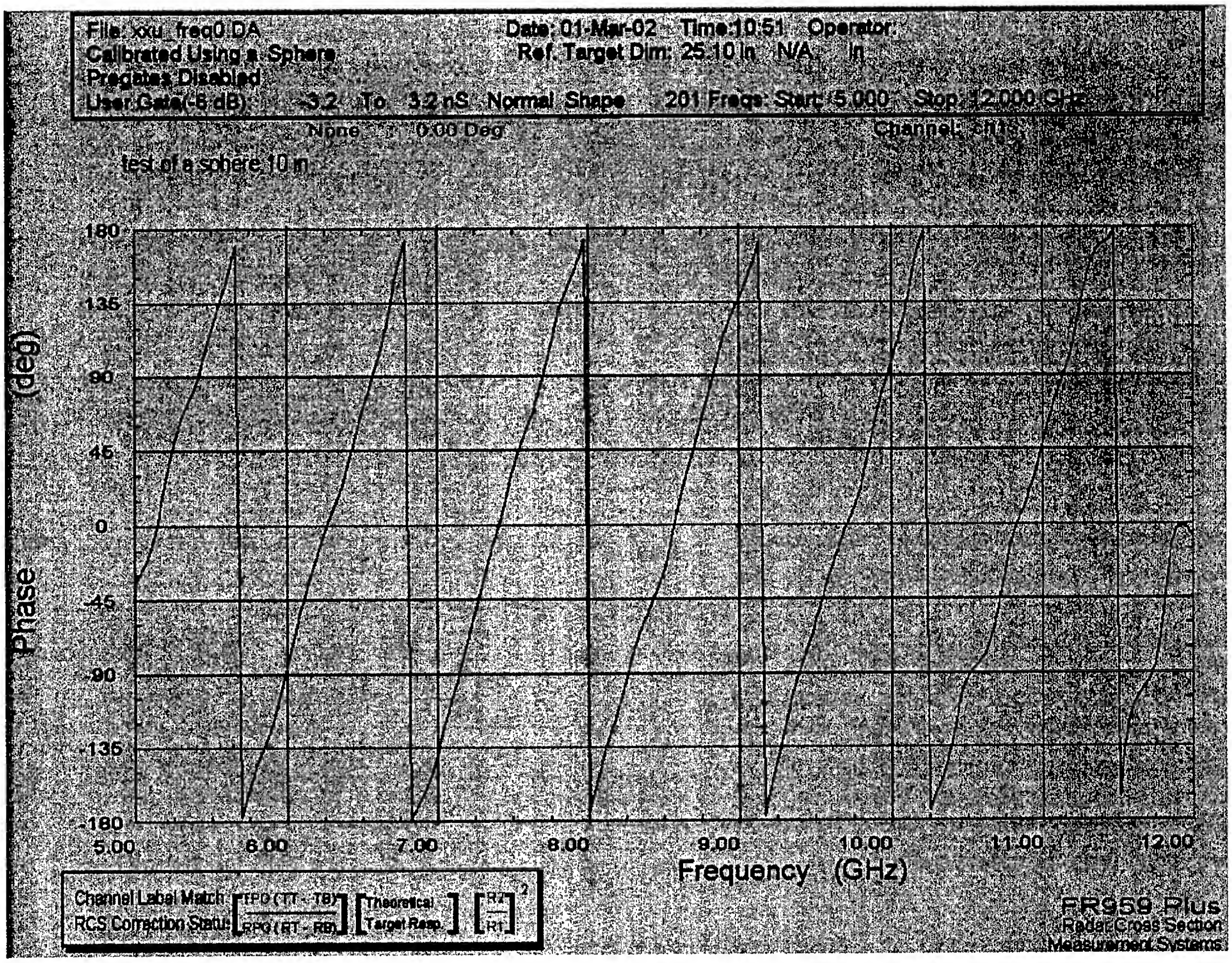

Figure 6: RCS phase vs. frequency of a metal sphere.

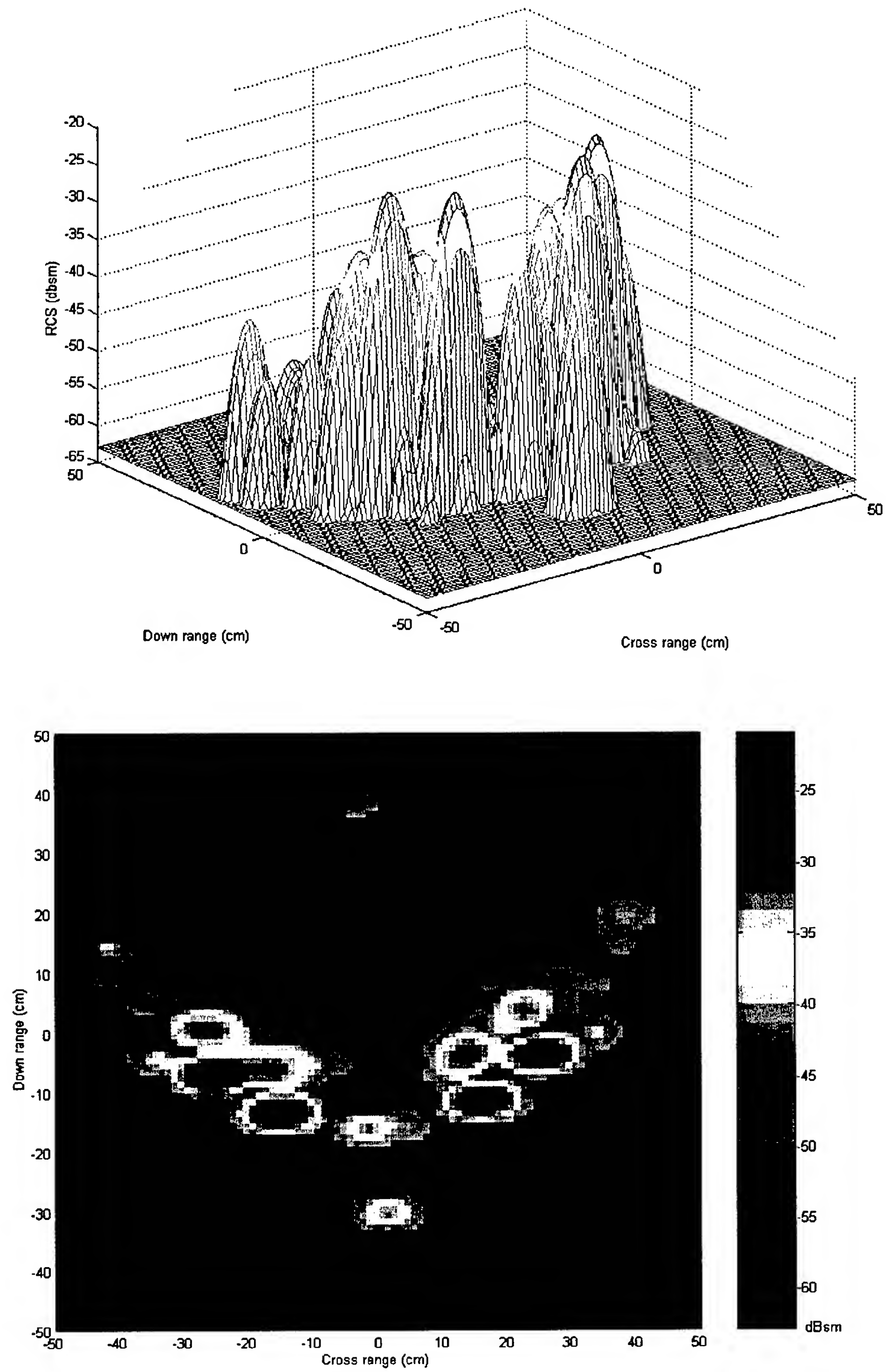

Figure 7: Two-dimensional images of an airplane model.

4 CONCLUSION

An antenna and Radar Cross Section (RCS) Instrumentation System operating over the 45 MHz - 26.5 GHz GHz frequency ranges was developed, which led to the completion of the Anechoic Chamber Facility at UNL. Some key features of the antenna and RCS measurement system include

- Frequency band: 45 MHz - 26.5 GHz, extendable to 50 GHz;
- RCS vs. frequency and azimuth measurement capability;
- Full polarimetric scattering matrix capability;
- One- and two-dimensional high resolution imaging capability;
- Antenna measurement capability; and
- Fully automated measurement and processing.

The completion of this facility results in a significant enhancement in research and research-related activities, and raise UNL's competitiveness in attracting increased DoD support. Further extensive measurements on more complex targets are planned for the future.

REFERENCES

1. Fred P. Brownell, "Radio frequency anechoic chamber," *Microwave Antenna Measurements Short Course.*

2. *85301B/C Antenna Measurement Systems 45MHz to 110 GHz, Configuration Guide*, Agilent Technologies, 2000.

3. *FR959 Antomated RCS Measurement Workstation, Operation Manual*, ORBIT/FR, 1999.

4. *RCS FR959 and DataPro Technical Reference Guide*, ORBIT/FR, 1999.

5. *DataPro RCS Data Presentation and Analysis, Operation Manual*, ORBIT/FR, 1999.